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June 8, 2001

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

BY HAND

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20554

Re: ***Ex Parte* Notification**
ET Docket No. 98-153
Ultra-Wideband

Dear Ms. Salas:

This is to note that on June 7, 2001, Michal Freedhoff and Paul Withington of Time Domain Corporation, Phillip Inglis, a consultant to Time Domain, and I met with Julius Knapp, Michael Marcus, Karen Rackley, and John Reed of the Office of Engineering and Technology. During part of the meeting, Ken Nichols, Richard Fabina, Tom Phillips, Art Wall and William Hurst of OET participated by telephone. We addressed the issues covered in the enclosed presentation pertaining to ultra-wideband.

Should any questions arise concerning this matter, please contact me.

Respectfully,

David E. Hilliard

David E. Hilliard
Counsel for Time Domain Corporation

Enclosure: Presentation
cc: Ms. Rackley, Messrs. Knapp, Marcus, Reed, Nichols, Fabina, Wall, Phillips, and Hurst

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THE PULSE OF THE FUTURE

UWB:
The 50 MHz Limit
&
Noise-likeness

Discussion Outline

- The 50 MHz Limit as presently proposed
  - What problems are created for the UWB industry by the 20 dB limit
  - Objective of the limit
  - Restrictive 20 dB limit in NPRM
  - Impact on UWB Technology
  - An appropriate peak limit
  - A 41 dB limit is a good balance
- Defining sufficient noise-likeness

Objective of the Peak-to-Average Limit

- The 20 dB peak limit as measured in a 50 MHz bandwidth was proposed as a means of controlling peak level interference
- Limits peak pulse amplitude thereby controlling peak-related interference potential
  - Prevents front-end overload in a victim receiver

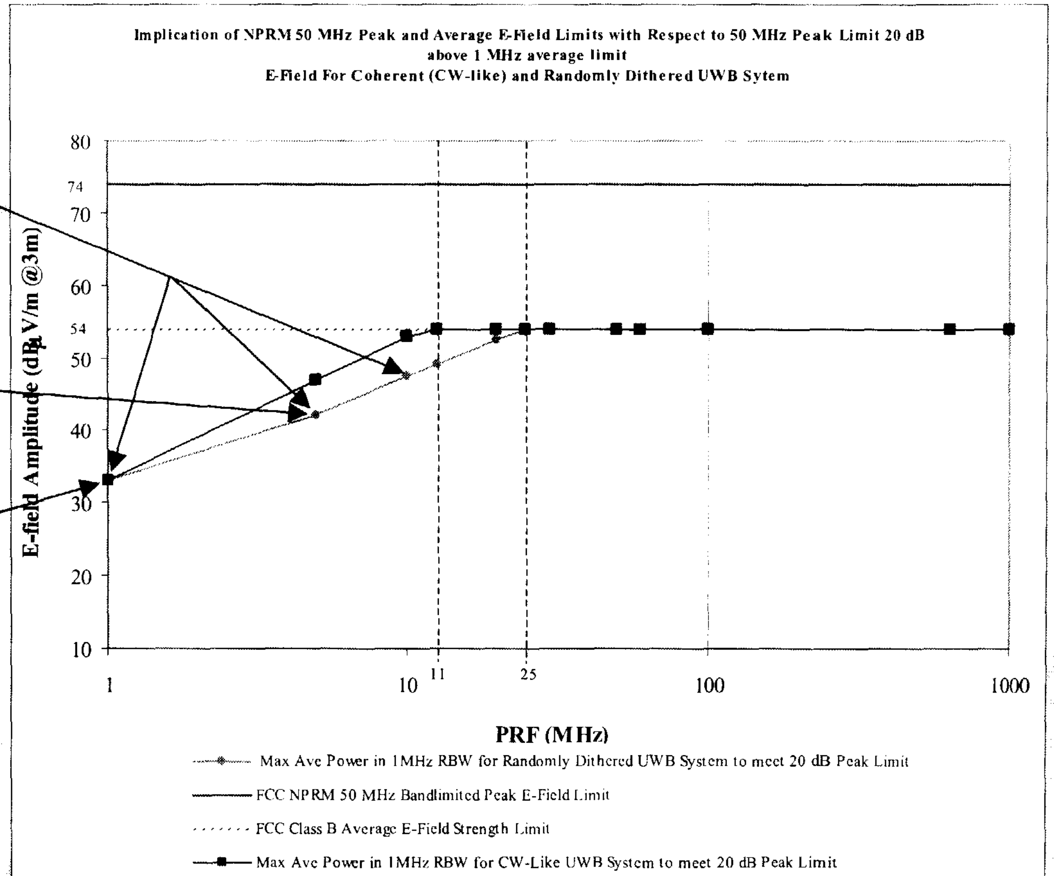
The 50 MHz Limit

- As proposed in the NPRM, the lower the PRF, the lower the reduction in average power has to be

TM-UWB Emitter PRFs Used for Texas GPS Testing

TDC Through-Wall Radar PRF & PRF of Emitter Used by TDC for Its GPS Test

Typical GPR PRF & Used in Texas Testing



Impact of the 20 dB limit on UWB Technology

- Using NTIA's Pulse Response Formulas, average power reductions can be calculated.
  - For dithered UWB technology, PRFs below 23-25 MHz are affected. For example, a 1 MHz PRF system would require a 21 dB reduction in average power.
  - For non-dithered technologies, PRFs below 11 MHz are affected. For example, a 1 MHz PRF system would require a 21 dB reduction in average power.

20 dB Value on 50 MHz Peak Limit is Problematic

- Restricts use of lower PRF systems
- Radar Applications – most are precluded
  - TDC's radar vision - (e.g., through-wall sensing)
    - Requires lower PRF for maximum range
    - Severe average power reduction is required
  - GPR in general has similar problems
- Applications also constrained
  - TDC's tracking system
  - Inventory monitoring
  - Medical communication & tracking applications

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Problems (cont'd)

- Restricting UWB applications to high PRFs may increase potential impact on GPS
  - GPS studies conclude that pulse-like signals (where PRF is smaller than RBW) are less of a problem for GPS than white noise or noise-like UWB signals.
  - Lower PRFs are more pulse-like than higher PRFs

Derivation of an Appropriate Peak Limit

- NTIA did not account for the proposed 20 dB peak to average limit and its effect on average power in its non-GPS report.

- NTIA did not reduce the average powers of the UWB systems tested, and as a result, the 1 MHz PRF systems actually had peak power levels that were 41 dB above the average limit.

- For 1 MHz PRF systems, dithered and non-dithered UWB signals evoke the same response level in a 50 MHz measurement bandwidth.

Comments on NTIA's Average Power Analysis

- NTIA analyzed 15 non-GPS systems in the 1-6 GHz range for average UWB power susceptibility.
- PRFs below 1 MHz generally showed a 10 dB higher interference potential
  - A 10 dB/decade reduction in average power for UWB PRFs below 1 MHz will equalize average power interference potential for PRFs over the 0.001 MHz to 500 MHz range.
  - A 41 dB peak limit forces this 10 dB/decade reduction in average power below 1 MHz PRFs, negating the 10 dB higher interference potential noted by NTIA.

NTIA Criteria Not Exceeded Using a 41 dB Limit

- Implementing an average power reduction for low PRF systems based on a 41 dB peak to average ratio, and incorporating an additional path loss figure, shows that UWB devices operating at – 41.3 dBm EIRP power levels will not exceed the protection criteria NTIA used in its analysis.

Comments on NTIA's Peak Power Analysis

- Of the 15 non-GPS systems examined by NTIA, 2 communications systems were further analyzed based on UWB peak power susceptibility.
- NTIA used a 1 dB increase in the system noise floor as its criterion for harmful interference in lieu of the the industry standard C/I ratio criterion.
  - For the SARSAT station, NTIA calculated a minimum separation distance of 11.3 km for a 1 MHz PRF UWB power level of -41.3 dBm
  - For the FSS Earth Station (5° elevation), NTIA calculated a minimum separation distance of 10.1 km for a 1 MHz PRF UWB power level of -41.3 dBm

Peak Power Analysis for SARSAT and FSS Using the Industry C/I Ratio

- First, calculate the path loss:
  - Lp=C/I-C+Pt+Gt+Gr-Ls-Lr-FDR
  - Source: NTIA Report 94-313 "Analysis of electromagnetic compatibility between radar stations and 4 GHz fixed-satellite Earth stations", July 1994
- Then, solve for D, the minimum separation distance, using the Hata model for urban environments
  - Lp=32.4+20logF+20logD
- When parameters for SARSAT and FSS systems given in NTIA reports and FCC proposed limits for UWB power levels for a 1 MHz system are used, the required separation distance is only 5 meters for SARSAT and 26 meters for FSS!

Peak-Related Interference Results Comparison

NTIA non-GPS Criterion	Industry Standard Criterion
SARSAT – 11.3 km	SARSAT – 5 m
FSS – 10.1 km	FSS – 26 m

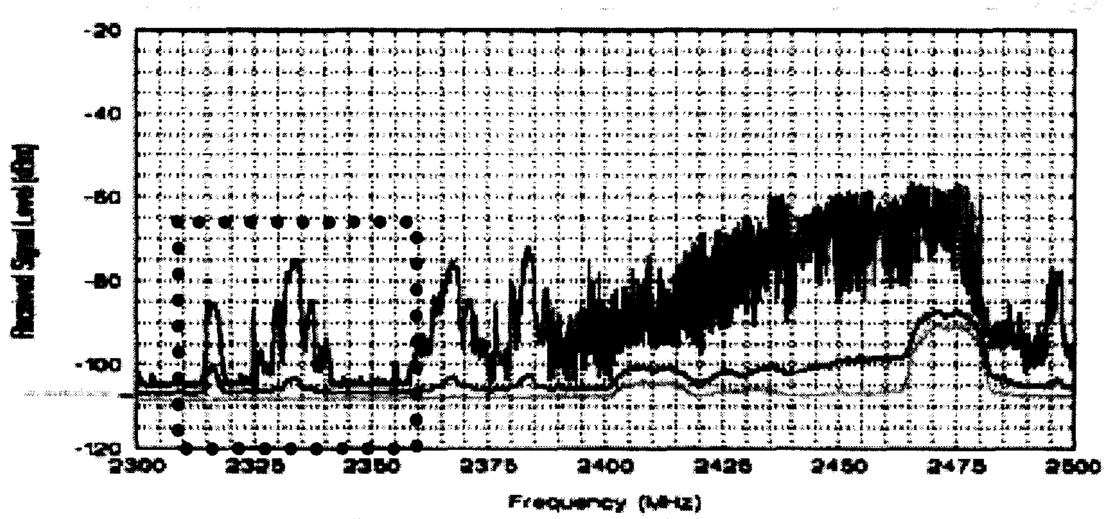
- NTIA'S analysis used incorrect performance criterion (raising noise floor by 1 dB vs. industry standard C/I ratio).
- NTIA Report 94-313 related to radar interference did use the industry standard approach

Other Factors That Further Reduce the Impact of UWB

- Worst-case calculation by NTIA that led to the 10.2 and 11.3 km distances assumed an undithered UWB signal.
- Worst-case calculation by NTIA that led to the 10.2 and 11.3 km distances assumed UWB height of 30m – this only makes sense if the UWB device were indoors, which adds further attenuation.
- NTIA assumed that the SARSAT and FSS antennas were aimed at the UWB source – no correction for off-axis antenna alignment.
- At low elevation angles, FSS systems would also detect radar signals that would likely be at higher powers than UWB is proposed to be.

Consumer Satellite Services in the 2 TO 2.5 GHZ Band

- NTIA Technical Memorandum 92-154 shows emissions in the 2310 to 2360 MHz band
  - Radars
  - Microwave ovens
  - ISM-band industrial equipment
- "Above 2350 MHz, the probability is high that the BSS receiver will detect microwave oven pulses consistently above its threshold in any of its intended operating environments."
- "Below 2350 MHz, pulse amplitudes are lower, but still above the threshold at short distance in a home or between apartments."



Source: NTIA Broadband Survey of San Diego, CA

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Emissions from Microwave Ovens

- Another NTIA report emphasizes the noise level in the 2310 to 2360 MHz band

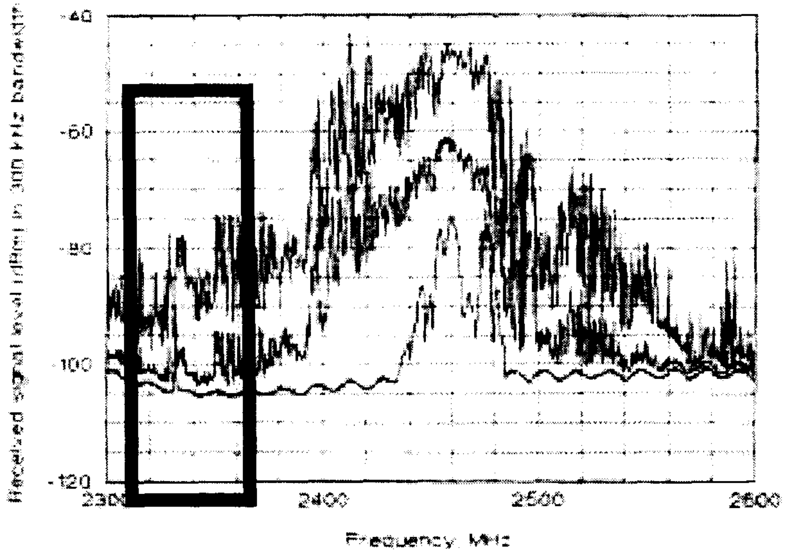

Figure 3-11. Aggregate emission spectrum outside apartment complex
4:30 -7:30 PM weekday

Source: NTIA Technical Memorandum 92-154

Noise-likeness

- Time Domain believes that a test for UWB noise-likeness makes sense.
- A properly designed UWB signal is like, but not identical to, white noise.
- Using too narrow an RBW favors high PRF systems

Conclusion

- A 41 dB peak to average limit poses no interference threat, and allows for the deployment of a wide range of UWB applications.
- Peak power effects reported by NTIA for SARSAT and FSS are incorrect and overstated.
- A test for noise-likeness should be applied carefully.

NTIA TM-92-154

ACCOMMODATION OF BROADCAST SATELLITE (SOUND) AND MOBILE SATELLITE SERVICES IN THE 2300-2450 MHz BAND

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JANUARY 1992

ACKNOWLEDGEMENT

This project could not have been completed without the efforts of the National Telecommunications and Information Administration (NTIA) Institute for Telecommunication Sciences (ITS). The ITS Spectrum Use Measurement Group provided data taken with the Radio Spectrum Measurement System and analysis of the measured data. Technical support from Gary D. Gierhart, Vince Lawrence and Robert J. Achatz was essential to the completion and analysis of the measurements.

ABSTRACT

This report provides a feasibility assessment of accommodating the Broadcast Satellite (Sound) Service and a Mobile Satellite Service uplink in the 2300-2450 MHz range. The assessment is based upon measurements by the Institute for Telecommunication Sciences of microwave oven and radio environment characteristics. Projected characteristics of the proposed services are considered.

KEY WORDS

BROADCAST SATELLITE (SOUND)
INDUSTRIAL, SCIENTIFIC, AND MEDICAL EQUIPMENT
MICROWAVE OVENS
MOBILE SATELLITE SERVICE
WARC-92

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

BACKGROUND 1-1
OBJECTIVE 1-2
APPROACH 1-2

SECTION 2

CONCLUSIONS

INTRODUCTION 2-1
GENERAL CONCLUSIONS 2-1
ACCOMMODATION OF BSS 2-2
ACCOMMODATION OF MSS 2-3

SECTION 3

ACCOMMODATION OF BSS IN THE 2300-2410 MHz RANGE

INTRODUCTION 3-1
KITCHEN ENVIRONMENT 3-1
APARTMENT INTERIOR ENVIRONMENT 3-12
APARTMENT COMPLEX EXTERIOR ENVIRONMENT 3-13
ANALYSIS SUMMARY 3-15

SECTION 4

ACCOMMODATION OF MSS IN THE 2390-2450 MHz RANGE

INTRODUCTION 4-1
MEASUREMENTS 4-1
ANALYSIS 4-3
ANALYSIS SUMMARY 4-10

APPENDIX

BSS INTERFERENCE MARGIN ANALYSIS

TABLE OF CONTENTS
(continued)

LIST OF FIGURES

3-1	Individual emission spectra	3-2
3-2	Microwave oven radiation pattern	3-4
3-3	Time waveforms 2410 MHz	3-5
3-4	Time waveforms 2390 MHz	3-6
3-5	Time waveforms 2360 MHz	3-7
3-6	Time waveforms 2350 MHz	3-8
3-7	Time waveforms 2330 MHz	3-9
3-8	Time waveforms 2310 MHz	3-10
3-9	Time waveforms 2300 MHz	3-11
3-10	Aggregate emission spectrum inside apartment 6:30-9:30 PM Saturday	3-14
3-11	Aggregate emission spectrum outside apartment complex 4:30-7:30 PM weekday	3-14
3-12	Apartment exterior amplitude probability distributions	3-16
3-13	60 Second time waveform outside apartment complex	3-17
4-1	Aggregate emission spectrum from Green Mesa	4-2
4-2	Aggregate emission spectrum from Flagstaff	4-2
4-3	Green Mesa APDs	4-4
4-4	Green Mesa aggregate time waveforms	4-5
4-5	ISM environment EIRP for Boulder	4-8

SECTION 1

INTRODUCTION

BACKGROUND

In preparing for the 1992 World Administrative Radio Conference (WARC-92), the United States considered allocating spectrum in the frequency range 2300-2410 MHz to the Broadcast Satellite (Sound) Service (BSS) and allocating spectrum in the frequency range 2390-2450 MHz to a Mobile Satellite Service (MSS) uplink. A concern in implementing these allocations is the operation near 2450 MHz of approximately 80 million microwave ovens in the United States and 200 million worldwide. Therefore, the United States has proposed that 2310-2360 MHz be allocated to BSS and 2390-2430 MHz be allocated to the MSS uplink.

The frequency 2450 MHz ± 50 MHz is designated for use by industrial, scientific, and medical (ISM) applications. ISM devices use radio frequency (RF) energy for purposes other than communications. Though consumer microwave ovens are not the only ISM devices in this band, they are by far the most prevalent. Outside the ISM band, Federal Communications Commission (FCC) regulations require that ISM emissions be suppressed below 25 μV/m at 300 meters. Inside the ISM band, their emissions are unrestricted.

Oven manufacturers have described their devices as efficient from a size, and cooking capability standpoint, and necessarily inexpensive for marketing to consumers. All of the ovens are built using magnetrons (predominantly built in Japan and Korea), which, in order to achieve certain design objectives and as a consequence of varied operating conditions, produce a relatively broad RF emission spectrum. The varied cooking depth produced by a range of frequencies is important to even cooking. The emission spectrum varies with such factors as the characteristics and location of the cooked load and the presence of built-in auxiliary devices, such as mode-stirrers. Though the oven cabinet substantially reduces emissions, external signal levels are considerable.

The designs for the proposed radio services are still under consideration, but preliminary characteristics have been discussed. A European prototype has been built for the BSS, and development is proceeding within the United States on a separate design. A variety of concepts for MSS have been proposed.

In order to determine the feasibility of the proposed allocation options, NTIA performed measurements in the 2300-2500 MHz range, and an analysis of the possible effects of the existing RF environment on the BSS and MSS systems.

OBJECTIVE

The objective of this task was to determine the feasibility of accommodating BSS between 2300 and 2410 MHz and MSS between 2390 and 2450 MHz.

APPROACH

Characteristics of the proposed BSS equipment were drawn from information provided by a representative of the French system developer, and the International Radio Consultative Committee (CCIR). These characteristics were used to determine the interference threshold of the BSS receivers. This threshold was then compared with the signal level generated by the microwave ovens as measured by the Institute for Telecommunication Sciences (ITS) under the following scenarios.

1. BSS receiver within 3 meters of a single microwave oven. This scenario simulates the potential interference to a radio receiver located in the kitchen, and can also be used to simulate conditions inside a single family house.

2. BSS receiver inside an apartment. This scenario simulates the potential interference to a radio from microwave ovens in nearby apartments.

3. BSS receiver outside, within a residential area. This scenario simulates the potential interference to a radio in a vehicle on the street.

MSS characteristics were estimated based upon ongoing discussion of system design proposals. Measured data of the aggregate environment signal levels in the band were collected on two hilltops overlooking Boulder, CO. The data were extrapolated to approximate the equivalent isotropic radiated power (EIRP) of the city as a single source and then to approximate the EIRP of a large metropolitan region. The carrier-to-interference ratio at the satellite receiver input was then estimated.

SECTION 2

CONCLUSIONS

INTRODUCTION

This report provides an assessment of the feasibility of accommodating BSS at 2300-2410 MHz and the MSS uplink at 2390-2450 MHz. The assessment is based upon measurements of individual microwave oven characteristics, the measured RF environment in the Boulder, CO area, and projected characteristics of the proposed services.

The following conclusions are based on the analysis contained in this report.

GENERAL CONCLUSIONS

Microwave ovens radiate signals outside their designated band (2450 ± 50 MHz). The out-of-band emissions are characteristic of the oven magnetron, but also vary with the load position, the load moisture content, and the incorporation of mode stirrers or turntables in the oven design. Measurements indicated that the aggregate signal from ISM sources becomes more impulsive the farther the frequency from 2450 MHz, thereby increasing the potential for accommodation of the proposed services with frequency separation.

Designs for proposed BSS and MSS systems are being developed for an environment of severe multipath and fading. Digital processing, error correction techniques, and power budgets employed by these services need to account for the presence of microwave oven signals, when operating in this frequency band, recognizing that the level of these signals decreases with the separation from 2450 MHz. There is no conclusive evidence that, given adequate consideration of the RF environment, these services cannot be accommodated.

The competition for spectrum by new and innovative services makes the existence of out-of-band microwave oven signals a subject of increasing importance. By reducing and confining the out-of-band signals, the adjacent bands could be made more compatible to the introduction of new telecommunications services. The extended timeframe inherent to the introduction of new services could complement the redesign, development of new product lines, and the natural replacement of the existing ovens.

The following provides more specific conclusions.

Microwave Oven Emission Characteristics

1. The maximum emission levels of microwave ovens occur at 2450 MHz. The ovens emit pulses approximately 8 milliseconds in duration with a 50% duty cycle. However, due to the combination of the magnetron output characteristics and of the absorption characteristics of the cooked substances, the ovens radiate pulses across a wide range of frequencies.

2. The amplitude and probability of occurrence of microwave oven pulses generally decrease as the frequency separation from 2450 MHz increases, with the exception of a secondary peak characteristic of most of the ovens tested somewhere between 2350 and 2380 MHz. Therefore, aggregate emissions from the ovens produce receiver responses of a noise-like nature near 2450 MHz, becoming increasingly impulsive below 2430 MHz. The ovens emit significant levels of RF energy below the 2400-2500 MHz ISM band. The emission levels above 2450 MHz fall off much more rapidly, dropping sharply above 2480 MHz for all ovens tested.

3. Below 2400 MHz and down to 2360 MHz, the microwave oven emissions may still produce receiver amplitude responses for the entire pulse duration at low signal levels. Below 2360 MHz, receiver responses show impulse spikes coincident with the beginning and ending of each pulse. However, in some cases, the impulse responses broaden at their base to 1-2 milliseconds duration.

4. The radiation patterns of microwave ovens are generally omnidirectional.

Proposed Radio Service Design Characteristics

1. The BSS and MSS technologies are still being specified, tested, and developed, including their interference protection capabilities.

2. BSS and MSS system developers will have to account for the environment of multipath, fading, and interference through sophisticated signal processing and error correction techniques. Also, careful consideration of system power budgets will be essential in service planning.

ACCOMMODATION OF BSS

1. At the frequency 2360 MHz and higher, the BSS receiver may not be able to operate unless regulatory action is taken to reduce the microwave oven out-of-band emissions. In that frequency range, in the current environment, the probability is high that the BSS receiver will

detect microwave oven pulses in any of its intended operating scenarios. The receiver response may often include oven pulses of 8 millisecond duration and near 50% duty factor.

2. Below 2360 MHz, pulses occur less frequently, are lower in amplitude, and usually produce the leading and trailing edge impulses responses in the receiver. However, peaks are still above the thresholds calculated using CCIR Report 955-2 and CCIR Document JIWP92/115-E.[1] Sophisticated signal processing techniques, such as time and frequency interleaving and forward error correction, presently being implemented to mitigate difficulties related to fading and multipath, could provide adequate receiver performance in the presence of these narrow pulses.

3. In an era of increasing spectrum use, implementation of new and innovative radiocommunications services, such as BSS, can also be facilitated through improved spectrum efficiency of existing systems and the mitigation of interference. In this case, the reduction of out-of-band emissions from ISM equipment could make the 2300-2400 MHz band more "friendly" to innovative uses. The period required to bring about such improvements in microwave oven design through the regulatory process may coincide with the time needed to develop and implement a BSS system.

4. CCIR specifications found in CCIR Report 955-2 and CCIR Document JIWP92/115-E reflect a system performance with no margin for external interference, and limited margin for intra-system interference.

5. Increasing satellite transmitter power and decreasing antenna beamwidths may provide adequate performance improvement; however, limits exist to the total satellite power. Increasing power per channel will decrease the number of usable channels.

ACCOMMODATION OF MSS

1. Since, above 2430 MHz, the aggregate emissions appear noise-like, and population within satellite beamwidths will produce additive increases in interfering signal level, accommodation of this service near 2450 MHz will be difficult.

---

1 CCIR Report 955-2, Satellite Sound Broadcasting with Portable Receivers and Receivers in Automobiles, CCIR Plenary Assembly, Dusseldorf, 1990; CCIR Document JIWP92/115-E, Section 5.1 of Document JIWP92/115, CCIR Joint Interim Working Party WARC-92, Geneva, 4-15 March 1991.

2. Below 2430 MHz, the increasingly impulsive characteristic of the aggregate noise will make its effects less additive. Therefore, adequate performance of the MSS system could be possible.

3. The task of determining the feasibility of MSS accommodation is hindered by the lack of defined system parameters and protection ratios. Also, the characterization of the east coast, based upon an extrapolation from the Boulder, CO environment has inherent risks. Though aggregate measurements can account for the variables associated with single emitters, the aggregate environment of Boulder, a "high tech", research, and university oriented city, may be significantly different from an industrial city. Furthermore, the measurements, though taken on hilltops, may still not adequately represent the emission levels in a more vertical direction.

4. The EIRP limitations associated with the use of handheld transmitters may be the primary limitation. Higher EIRPs associated with vehicle mounted transmitters and antennas may provide the needed margin. Other techniques may also lower the required carrier-to-interference ratio requirements.